Claims

What is claimed is:

1. An electronic thermometer comprising:

a probe tip separated from a probe shaft by a thermal isolator disposed therebetween; and

a probe tip temperature sensor disposed proximate to said probe tip.

2. The electronic thermometer according to claim 1 further comprising a proximal temperature sensor wherein said proximal temperature sensor is thermally isolated from said probe tip.

3. The electronic thermometer according to claim 1 further comprising a temperature prediction component electrically connected to a probe tip temperature sensor wherein said probe tip temperature sensor is disposed proximate to said probe tip.

4. The electronic thermometer according to claim 3 wherein said temperature prediction component is electrically connected to a proximal temperature sensor wherein said proximal temperature sensor is thermally isolated from said probe tip.

5. The electronic thermometer according to claim 4 further comprising a temperature prediction component wherein said temperature prediction component is operative to calculate a predicted temperature using an optimized temperature prediction algorithm.

6. The electronic thermometer according to claim 1 further comprising a heater element thermally isolated from said probe tip.

7. The electronic thermometer according to claim 6 further comprising a temperature control circuit providing controlled power to said heater element.

8. The electronic thermometer according to claim 7 wherein said temperature control circuit receives input from at least one temperature sensor and actively controls power to said heater element according to said input using an optimized heater control algorithm.

9. The electronic thermometer according to claim 6 wherein said heater element raise the temperature of said probe shaft that is thermally isolated from said tip and impedes heat flow from said probe tip to said probe shaft.

10. An electronic thermometer comprising:

a probe shaft having a distal end and a proximate end;

a separator mounted between said distal end and a thermal isolator;

wherein said thermal isolator is disposed between and thermally isolates said separator and a probe tip;

a heater element in thermal contact with said separator; and

a probe tip temperature sensor element in thermal contact with said probe tip.

11. The electronic thermometer according to claim 10 further comprising a proximal temperature sensor element in thermal contact with said thermal isolator.

12. The electronic thermometer according to claim 11 wherein said probe tip temperature sensor is mounted against said probe tip, and wherein said proximal temperature sensor is mounted against said thermal isolator.

13. The electronic thermometer according to claim 12 wherein at least one of said probe tip temperature sensor and said proximal temperature sensor is a thermistor.

14. The electronic thermometer according to claim 11 further comprising an active heater control circuit wherein said active heater control circuit causes said heater element to raise the temperature of said probe shaft in response to signals from said probe tip temperature sensor.

15. The electronic thermometer according to claim 14 wherein said active heater control circuit causes said heater element to raise the temperature of said shaft in response to signals from said proximal temperature sensor.

16. The electronic thermometer according to claim 10 further comprising a temperature prediction component wherein said temperature prediction component calculates a predicted equilibrium temperature according to signals from said probe tip temperature sensor acquired prior to said probe tip temperature sensor reaching thermal equilibrium with a measured subject.

17. The electronic thermometer according to claim 16 wherein said temperature prediction component causes an output device to provide an indication of said predicted equilibrium temperature prior to said sensor reaching thermal equilibrium with said measured subject.

18. The electronic thermometer according to claim 16 wherein said temperature prediction component calculates said predicted equilibrium temperature according to a least square fit algorithm.

19. The electronic thermometer according to claim 16 wherein said temperature prediction component calculates said predicted equilibrium temperature according to the following equations:

$$T_b = T_p(R_1C_1 + R_2C_2 + R_1C_2 + (1-k)(R_3C_3 + R_2C_2 + R_1C_3))$$
$$+ \ddot{T}_p(R_1C_1R_2C_2 + (1-k)(R_1C_1R_2C_3 + R_3C_3R_1C_1 + R_2C_2R_3C_3 + R_1C_2R_3C_3))$$
$$+ \dddot{T}_p R_1C_1R_2C_2R_3C_3(1-k)\ .$$

which, when combined with the effects of our heater algorithm, can be modeled as:

$$T_p(t) - T_p(0) = \frac{t - t_0}{a \bullet (t - t_0) + b}$$

simplifying to linear form

$$\frac{t - t_0}{T_p - T_p(0)} = a \bullet (t - t_0) + b$$
$$T_{final} = \frac{1}{a} + T_p(0)\ .$$

20. The electronic thermometer according to claim 15 wherein said active heater control circuit uses a substantially optimized algorithm programmed in a digital control device to cause substantially instantaneous changes in heater current in response to temperature sensor signals.

21. The electronic thermometer according to claim 20 wherein said substantially optimized algorithm is predetermined according to thermal characteristics of said probe for rapid tracking of probe tip temperature by probe shaft temperature.

22. The electronic thermometer according to claim 20 wherein said substantially optimized algorithm comprises the following equations:

Errorlast=Errornow;

Errornow=SP-Tptemp;

DutyCycle=(int)(Apreheat*Errornow + Bpreheat*(Errornow-Errorlast) + 0.5);

wherein:

Errorlast is a variable for storing the previously determined Errornow value;

Errornow is a variable storing the difference between the point temperature and a measured probe tip temperature;

DutyCycle is a variable representing the percentage of time to apply heater current;

SP = 35 C;

Tptemp = probe tip temperature sensor data in degrees C; and

Apreheat and Bpreheat = constants that depend on power supply voltage level.

23. The electronic thermometer according to claim 1 further comprising a base component connected to said probe shaft by a flexible cable wherein said flexible cable includes conductors carrying temperature sensor signals and conductors carrying current to said heater element.

24. The electronic thermometer according to claim 23 wherein said base component houses control components for said heater element and temperature prediction components, said base component further including output devices in communication with said heater control components and said temperature prediction components.

25. The electronic thermometer according to claim 10 further comprising a thermal epoxy disposed between said probe tip and said separator.

26. The electronic thermometer according to claim 10 wherein said thermal isolator is made from HPDE - EXXON Escorene HD 6801YN or HPDE - Dow 25455N.

27. A method of rapidly measuring the temperature of a subject comprising the steps of:

thermally insulating a thermometer probe tip including a temperature sensor from a thermometer probe shaft;

heating said thermometer probe shaft;

reading a temperature sensor signal from said temperature sensor; and

predicting an equilibrium temperature according to a prediction algorithm which operates according to said temperature sensor signal.

28. The method according to claim 27 wherein said step of heating said thermometer probe shaft further comprises the steps of:

reading a temperature sensor signal from said temperature sensor;

computing an optimal heater current control signal according to a heater control algorithm which operates according to said temperature signal; and

applying said heater current control signal to a heater current control component.

29. The method according to claim 28 wherein said heater current control algorithm comprises the steps of:

storing a previously determined temperature error value;

determining a temperature error value by subtracting said temperature sensor signal from a set point;

determining a duty cycle by:

multiplying said error value by a first preheat constant to obtain a first result;

multiplying a second preheat constant by the difference between said temperature error value and said a previously determined temperature error value to obtain a second result;

adding 0.5 to said first result plus said second result to obtain a third result;

and truncating a decimal portion of said third result;

wherein said first preheat constant and said second preheat constant depend on power supply voltage level.

30. The method according to claim 27 wherein said prediction algorithm comprises the steps of:

performing a curve fit to fit probe tip temperature data to a first equation:

$\frac{t-t_0}{T_p - T_p(0)} = a \bullet (t - t_0) + b$; wherein T_p = probe tip temperature; and

applying the "a" term in said first equation to a second equation:

$T_{final} = \frac{1}{a} + T_p(0)$; wherein T_{final} is the predicted final temperature.

31. The method according to claim 30 wherein said steps of performing a curve fit to fit probe tip temperature data to a first equation:

$\frac{t-t_0}{T_p - T_p(0)} = a \bullet (t - t_0) + b$; wherein T_p = probe tip temperature; and

applying the "a" term in said first equation to a second equation:

$T_{final} = \frac{1}{a} + T_p(0)$; wherein T_{final} is the predicted final temperature

are performed multiple times wherein each time said steps are performed a distinct value of $T_p(0)$ is used; and

selecting a best value of T_{final}.

32. The method according to claim 31 wherein said best value is selected by using metrics.

33. The method according to claim 31 wherein said multiple times equals seven times.

34. An electronic prediction thermometer comprising:

means for thermally isolating a thermometer probe tip including a temperature sensor element from a thermometer probe shaft;

means for applying heat to said thermometer probe shaft;

means for reading a temperature signal from said temperature sensor element and predicting an equilibrium temperature according to said signal read from said temperature sensor element.

35. An electronic prediction thermometer according to claim 34 further comprising means to control said heat applied to said to thermometer probe shaft according to said signal read form said temperature sensor element.

36. An electronic thermometer comprising:

a probe shaft having a distal end and a proximate end;

a separator mounted against said probe shaft;

an thermal isolator disposed over said distal end of said shaft;

a resistor capable of heating said separator connected to a heater control component;

a probe tip mounted to said thermal isolator at said distal end of said shaft and thermally isolated from said probe shaft, said separator and said heater element;

a first thermistor element mounted to said probe tip and connected to said heater control component and a temperature prediction component;

a second thermistor element mounted to said thermal isolator and connected to said heater control component and said temperature prediction component;

wherein said heater control component comprises an active heater control circuit that causes said resistor to raise the temperature of said separator in response to signals from said thermistors; and

wherein said temperature prediction component computes a predicted equilibrium temperature according to signals form said thermistors, said signals being acquired before thermistors reach equilibrium with a measured subject.

37. The electronic thermometer according to claim 36 wherein said temperature prediction component calculates said predicted equilibrium temperature according to the following equation:

$$T_b = T_p(R_1C_1 + R_2C_2 + R_1C_2 + (1-k)(R_3C_3 + R_2C_2 + R_1C_3))$$
$$+\ddot{T}_p(R_1C_1R_2C_2 + (1-k)(R_1C_1R_2C_3 + R_3C_3R_1C_1 + R_2C_2R_3C_3 + R_1C_2R_3C_3))$$
$$+\dddot{T}_p R_1C_1R_2C_2R_3C_3(1-k)\,.$$

which, when combined with the effects of a heater algorithm, can be modeled as:

$$T_p(t) - T_p(0) = \frac{t-t_0}{a \bullet (t-t_0) + b}$$

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$$\frac{t-t_0}{T_p - T_p(0)} = a \bullet (t-t_0) + b$$
$$T_{final} = \frac{1}{a} + T_p(0)\,.$$